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Inhibitory Activity of Corn Gluten Hydrolysate on Monocotyledonous and Dicotyledonous Species

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Abstract. **Corn gluten hydrolysate (CGH) was evaluated in the greenhouse for its herbicidal activity on 19 selected monocotyledonous and dicotyledonous species. Treatments included CGH at 0, 1, 2, 4, and 8 g·dm^{-2}. Plant susceptibility was based on plant survival, shoot length, and root length. The germination and growth of all species were inhibited by the application of CGH at all rates. Black medic (*Medicago lupulina* L.), buckhorn plaintain (*Plantago lanceolata* L.), creeping bentgrass (*Agrostis palustris* Huds.), purslane (*Portulaca oleracea* L.), and redroot pigweed (*Amaranthus retroflexus* L.) were the most susceptible species, exhibiting more than 70% reduction in root length, 60% reduction in plant survival, and 52% reduction in shoot length with CGH at 1 g·dm^{-2}. Common lambsquarters (*Chenopodium album* L.), curly dock (*Rumex crispus* L.), dandelion (*Taraxacum officinale* Weber), giant foxtail (*Setaria faberi* Herrm.), large crabgrass [*Digitaria sanguinalis* (L.) Scop.], and yellow foxtail [*Setaria lutescens* (Weigel) Hubb.] exhibited more than 50% reduction in root length and plant survival at 1 g·dm^{-2}. Annual bluegrass (*Poa annua* L.), barnyardgrass [*Echinochloa crusgali* (L.) Beauv.], green foxtail [*Setaria viridis* (L.) Beauv.], orchardgrass (*Dactylis glomerata* L.), perennial ryegrass (*Lolium perenne* L.), quackgrass [*Agropyron repens* (L.) Beauv.], and velvetleaf (*Abutilon theophrasti* Medic.) survivial was reduced by 60% at 2 g·dm^{-2}. Annual ryegrass (*Lolium multiflorum* Lam.) was the least susceptible species.**

Developing plant-derived compounds as natural herbicides has been suggested as a potential approach to weed control (Lax et al., 1988; Liu and Christians, 1996; Lydon and Duke, 1987). Corn gluten meal (CGM) is one of the materials that has shown potential as a natural herbicide (Christians, 1993). CGM, the protein fraction of corn (*Zea mays* L.) grain, is a byproduct from corn wet-milling and is used as an animal feed. In the initial studies in turf, CGM inhibited root growth of germinating grasses, but did not damage plants that had formed a mature root system (Christians, 1993). CGM was subsequently considered a potential weed control product in strawberry (*Fragaria ×ananassa* Duch.) production systems (Nonnecke and Christians, 1993). Because CGM contains 10% N by mass, it has potential as a natural preemergence herbicide and fertilizer for turf and strawberry production systems.

Corn gluten hydrolysate (CGH), a water-soluble material derived from CGM through enzyme hydrolysis, was found to be more herbicidally active than CGM in controlled environments (Liu et al., 1994). In petri dish bioassays, with CGH at 0.236 g·dm^{-2} and higher, there was > 80% reduction in germination of creeping bentgrass, whereas there was <10% reduction for CGM at 0.473 g·dm^{-2}. In soil bioassays, CGM at 6.88 g·dm^{-2} was required for 100% inhibition of smooth crabgrass (*Digitaria ischaemum* Schreb.) establishment, but only 4.69 g·dm^{-2} was needed for CGH. CGH could potentially be used to fortify the CGM as an improved natural herbicide and fertilizer material (Nonnecke and Christians, 1993).

In a greenhouse screening study evaluating the efficacy of CGM on 22 plant species, it was demonstrated that susceptibility varied with species (Bingaman and Christians, 1995). The objective of the present study was to evaluate the effects of CGH on plant survival and shoot and root growth of 19 monocotyledonous and dicotyledonous plants.

Materials and Methods

Square plastic pots with a surface area of 42 cm^2 and a depth of 4 cm were filled with a Nicollet (fine-loamy, mixed, mesic Aquic Hapludoll) soil with an organic matter content of 6.2%, a pH of 7.7, P at 62 mg·kg^{-1}, and K at 229 mg·kg^{-1}.

Eleven monocotyledonous species, including annual bluegrass, annual ryegrass, barnyardgrass, creeping bentgrass, giant foxtail, green foxtail, large crabgrass, orchardgrass, perennial ryegrass, quackgrass, and yellow foxtail, were evaluated. Eight dicotyledonous species that included black medic, buckhorn plaintain, common lambsquarters, curly dock, dandelion, purslane, redroot pigweed, and velvetleaf were also evaluated. Seeding rates varied from 3 to 191 g·m^{-2}, depending on species (Table 1). All seeds were planted on the soil surface before powdered CGH was applied at 0, 1, 2, 4, and 8 g·dm^{-2}.

The 95 pots were placed on a mist bench where a 10 s of mist was applied at 20-min intervals for 3 to 7 d, depending on the germination rate of a particular species. Once seeds in the nontreated control pot reached a stable plant cover, all pots were moved to a greenhouse bench. Temperature was maintained in the range of 18 to 27 °C. The plants were subjected to drought stress for 5 d to kill plants with inhibited root systems before final data were taken. Plant susceptibility was assessed

Table 1. Seeding rate, germination, shoot length, and root length for nontreated control plants of the 19 species tested with corn gluten hydrolysate.

	Plant responses[z]				
Plant species	Seeding rate (g·m^{-2})	Days to complete testing	Germination (%)	Root length (mm)	Shoot length (mm)
Annual bluegrass	10	14	48	17	45
Annual ryegrass	105	13	64	60	50
Barnyardgrass	95	13	78	62	63
Black medic	36	16	12	10	25
Buckhorn plaintain	31	16	37	25	40
Common lambsquarters	19	18	21	10	25
Creeping bentgrass	3	14	75	20	37
Curly dock	19	13	48	11	40
Dandelion	2	14	49	9	37
Giant foxtail	41	14	55	25	53
Green foxtail	26	18	15	23	52
Large crabgrass	19	18	25	23	48
Orchardgrass	29	14	46	31	53
Perennial ryegrass	48	13	82	53	50
Purslane	12	13	55	17	30
Quackgrass	76	16	29	35	48
Redroot pigweed	7	14	28	14	27
Velvetleaf	191	16	13	28	47
Yellow foxtail	73	16	35	18	52

[z]All values are the average of three replications.

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by measuring the number of live plants in each pot, the average plant height of living plants in each pot, and the average root length of three living plants in each pot.

The study was replicated three times between 28 Feb. and 2 Apr. 1996. Data were analyzed as a factorial design using the analysis of variance procedure. The treatments were the factorial arrangement of 19 species and five rates. Data were converted using the equation of 100·(1- measurement/the value of the nontreated control) and expressed as percentage of reduction compared to the nontreated control. Mean comparisons using the least significant difference test at $P \leq 0.05$ ($LSD_{0.05}$) were used to assess treatment effects.

Results and Discussion

From 13 to 18 d were required to complete the test, depending on species (Table 1). Also, variations in nontreated control plants existed among species, with germination ranging from 12% to 82%, average shoot length ranging from 9 to 62 mm, and the average root length ranging from 25 to 63 mm. Plant survival, shoot length, and root length were significantly affected by the treatments (Table 2). The responses of plant survival, shoot length, and root length to CGH varied with rate and species.

Plant survival. CGH reduced the survival of all 19 broadleaf and grass species at all four application rates as compared with the nontreated controls (Table 3). The higher the application rate, the lower the survival, but there were interspecies variations in plant survival in response to the CGH treatments. Buckhorn plaintain, common lambsquarters, creeping bentgrass, and yellow foxtail were the most susceptible species, exhibiting >74% reduction at the lowest tested rate of CGH, 1 g·dm^{-2}. In an earlier study, CGM at 3.24 g·dm^{-2} was required to achieve a similar effect (Bingaman and Christians, 1995).

The second most susceptible species were barnyardgrass, black medic, curly dock, giant foxtail, large crabgrass, purslane, and redroot pigweed. These plants exhibited >50% reduction in plant survival with CGH at 1 g·dm^{-2}, and 85% reduction at 2 g·dm^{-2}. In contrast, there was only a 32% reduction from CGM at 3.24 g·dm^{-2} (Bingaman and Christians, 1995). Annual ryegrass, dandelion, green foxtail, perennial ryegrass, and quackgrass were the least susceptible with <32% reduction in survival at 1 g·dm^{-2}. At the application of 2 g·dm^{-2}, all 19 species had >50% reduction in plant survival. Black medic and buckhorn plaintain all died, and common lambsquarters, creeping bentgrass, curly dock, giant foxtail, orchardgrass, purslane, redroot pigweed, and yellow foxtail had >84% reduction in survival compared to the nontreated control. All species, except annual ryegrass, died at 8 g·dm^{-2}, the highest application rate.

There was no difference in plant survival of buckhorn plaintain, creeping bentgrass, and yellow foxtail among rates of CGH. For annual bluegrass, barnyardgrass, orchardgrass, quackgrass, and velvetleaf, significantly fewer plants survived at 2 g·dm^{-2} than at 1 g·dm^{-2}. CGH at 2 g·dm^{-2} was required to achieve >50% reduction in plant survival of annual ryegrass, green foxtail, and perennial ryegrass, and >4 g·dm^{-2} were required to kill all plants.

Average shoot length. CGH inhibited shoot growth of all 19 species, although there were interspecies differences (Table 4). Black medic, buckhorn plaintain, purslane, and redroot pigweed were the most sensitive species. Their shoot length was reduced by >56% with CGH at 1 g·dm^{-2}, whereas CGM at 3.24 g·dm^{-2} was required to reduce shoot length of these species by 21% (Bingaman and Christians, 1995). The shoot length of annual ryegrass, dandelion, perennial ryegrass, quackgrass, and velvetleaf was reduced the least with CGM at 1 g·dm^{-2}.

Black medic and buckhorn plaintain produced no shoots with CGH at 2 g·dm^{-2}. All the other species had >50% reduction at this rate. There was no difference in reduction of shoot length for black medic, buckhorn plaintain, common lambsquarters, creeping bentgrass, curly dock, purslane, and redroot pigweed at 2 g·dm^{-2} and higher. Annual ryegrass had the least reduction in shoot length of all species, 52% and 70% at 2 and 4 g·dm^{-2}, respectively. All species, other than annual ryegrass, which had an 84% reduction in shoot length, failed to grow shoots at 8 g·dm^{-2}.

Average root length. CGH reduced the root length of all species at all four application rates (Table 5). Root length of creeping bentgrass was reduced 99% with GCH at 1 g·dm^{-2} in this study and 95% with CGM at 3.24 g·dm^{-2} in the other study (Bingaman and Christians, 1995). CGH at 1 g·dm^{-2}, annual bluegrass, black medic, buckhorn plaintain, common lambsquarters, curly dock, dandelion, giant foxtail, green foxtail, large crabgrass, purslane, quackgrass, and redroot pigweed had 60% or more reduction in root length. Annual ryegrass, barnyardgrass, orchardgrass, and velvetleaf had the least root reduction at 1 g·dm^{-2}. There were no differences in root length reduction

Table 2. Analysis of variance of the effects of corn gluten hydrolysate (CGH) on plant survival, shoot, and root lengths of 19 plant species.

	Statistic		
Variable	df	MS	$P > F$
Plant survival			
Replication	2	1400	0.0006
Species	18	880	0.0001
Rate	4	93595	0.0001
Species × rate	72	241	0.0706
Error	188	182	
Shoot length			
Replication	2	606	0.0382
Species	18	927	0.0001
Rate	4	92193	0.0001
Species × rate	72	205	0.2663
Error	188	182	
Root length			
Replication	2	473	0.0377
Species	18	279	0.0132
Rate	4	105481	0.0001
Species × rate	72	171	0.1612
Error	188	142	

Table 3. Effect of corn gluten hydrolysate (CGH) on the survival of 19 plant species. Data are expressed as percentage reduction in plant survival compared to the nontreated control.

	Reduction in plant survival[z] (%)			
	CGH (g·dm^{-2})			
Plant species	1	2	4	8
Annual bluegrass	45	72	91	100
Annual ryegrass	20	63	79	90
Barnyardgrass	51	75	100	100
Black medic	63	100	100	100
Buckhorn plaintain	95	100	100	100
Common lambsquarters	75	85	100	100
Creeping bentgrass	82	97	100	100
Curly dock	61	89	100	100
Dandelion	48	58	95	100
Giant foxtail	56	86	96	100
Green foxtail	31	53	78	100
Large crabgrass	59	69	94	100
Orchardgrass	44	81	92	100
Perennial ryegrass	31	76	80	100
Purslane	61	92	100	100
Quackgrass	42	81	87	100
Redroot pigweed	69	88	99	100
Velvetleaf	49	77	95	100
Yellow foxtail	82	90	97	100

[z]All values are the average of three replications. $LSD_{0.05}$ was 22% for the comparison of all means for all species.

Table 4. Effect of corn gluten hydrolysate (CGH) on the shoot length of 19 plant species. Data are expressed as percentage reduction in shoot length compared to the nontreated control.

	Reduction in shoot length[z] (%)			
	CGH ($g \cdot dm^{-2}$)			
Plant species	1	2	4	8
Annual bluegrass	33	68	86	100
Annual ryegrass	15	52	70	84
Barnyardgrass	36	72	89	100
Black medic	57	100	100	100
Buckhorn plaintain	77	100	100	100
Common lambsquarters	43	83	100	100
Creeping bentgrass	53	86	100	100
Curly dock	42	86	100	100
Dandelion	24	56	80	100
Giant foxtail	35	69	87	100
Green foxtail	38	61	75	100
Large crabgrass	53	59	77	100
Orchardgrass	35	75	86	100
Perennial ryegrass	21	69	81	100
Purslane	70	82	100	100
Quackgrass	29	65	77	100
Redroot pigweed	61	82	98	100
Velvetleaf	32	71	94	100
Yellow foxtail	34	64	82	100

[z]All values are the average of three replications. $LSD_{0.05}$ was 22% for the comparison of all means for all species.

Table 5. Effects of corn gluten hydrolysate (CGH) on the root growth of 19 plant species. Data are expressed as percentage reduction in root length compared to the nontreated control.

	Reduction in root length[z] (%)			
	CGH ($g \cdot dm^{-2}$)			
Plant species	1	2	4	8
Annual bluegrass	60	99	100	100
Annual ryegrass	27	85	94	100
Barnyardgrass	38	98	100	100
Black medic	76	100	100	100
Buckhorn plaintain	76	100	100	100
Common lambsquarters	67	94	100	100
Creeping bentgrass	99	100	100	100
Curly dock	66	96	100	100
Dandelion	69	100	100	100
Giant foxtail	70	98	100	100
Green foxtail	65	95	100	100
Large crabgrass	60	90	97	100
Orchardgrass	41	96	100	100
Perennial ryegrass	43	95	97	100
Purslane	71	100	100	100
Quackgrass	62	96	100	100
Redroot pigweed	74	100	100	100
Velvetleaf	39	93	100	100
Yellow foxtail	51	86	96	100

[z]All values are the average of three replications. $LSD_{0.05}$ was 19% for the comparison of all means for all species.

among all 19 species at 2 $g \cdot dm^{-2}$ and higher rates.

In general, with the exception of creeping bentgrass, dicotyledonous species had larger reductions in plant survival, shoot length, and root length than did monocotyledonous species. Less CGH was required to achieve the same degree of inhibition as that reported earlier for CGM. CGH has the added advantage of being water soluble and has the potential to be used as a natural herbicide product for the control of many broadleaf and grass species.

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